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ABSTRACT

Intended to lend organization to the educational media research in visual perception and learning with line drawings, this paper reviews studies that cut across several specialized fields of education and psychology. The studies reviewed are arranged into the following categories: (1) learning from visuals, (2) abstract versus realism theories, (3) visual cues, (4) modes of presentation, and (5) verbal and visual memory processes. The paper concludes that research in this area is often equivocal, leading to the evolution of many conflicting theories. (FL)

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THE PSYCHOLOGY OF VISUAL PERCEPTION AND LEARNING FROM LINE DRAWINGS: A SURVEY OF THE RESEARCH LITERATURE

by

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Introduction

This is a comprehensive survey of the educational media research in visual perception and learning with line drawings. This is a very wide body of research which cuts across several specialized fields of education and psychology. Therefore this survey is arranged by topics. The areas addressed are: learning from visuals, abstract vs. realism theories, visual cues, modes of presentation, and verbal and visual memory processes.

Learning from Visuals

It has been generally assumed that stimuli presented in a visual medium are superior to those presented in traditional verbal channels. This assumption has led to an abundance of two-dimensional visual stimuli in the form of pictures, photographs, line drawings, diagrams, charts, exploded drawings, etc. Visuals are abundantly utilized either alone or as adjunct aids in textbooks and a multiplicity of instructional materials (Bourisseau, Davis, and Yamamoto, 1965).

Research does not always support the notion that a "picture is worth a thousand words." The mechanism associated with pictorial instruction is complex and involves an interrelated memory system associated with an individual's ability to observe, interpret, and recall pictorial stimuli (Holliday, 1973, p. 201). Many of the negative comments on the value of pictures have resulted from research with the mental processing stimuli and what is known as the verbal loop hypothesis (Glanzer and Clark, 1963). It states that verbal and visual stimuli are processed in a single system (Levie and Levie, 1975, p. 81). Other research indicates

that visually mediated instruction does not produce a greater amount of learning compared to other verbal types of instruction (MacLennan and Reid, 1967; Dwyer, 1972; Chu and Schramm, 1973). The effectiveness of simple visuals may add or detract from learning depending on the specific learning objective to be realized (Swanson, Lumsdaine, and Aukes, 1956; Gropper, 1973; and Dwyer, 1972, 1978). Dwyer (1972) found that oral presentation without visuals was equally as effective as visually complemented treatments in areas of comprehension and terminology (p. 22). Levie (1973) completed a review of the literature in the area of pictorial representation. The conclusion was that the visuals which are used to teach specific objectives which actually require visual treatments are more effective in facilitating student learning than visuals which may be added for other reasons such as to add to student interest. Visuals with irrelevant details may actually decrease student learning (Lordahl, 1961; Hunt, 1962; Walker and Bourne, 1961). Further, under some conditions involving sequential memory tasks, words only treatments result in improved student performance (Paivio & Csapo, 1969, 1971).

When pictures are compared to words in experimental learning tasks, there are usually significant differences due to differences in stimuli. Pictures have been demonstrated to result in better performance in recognition memory tasks (Snodgrass, Volvovitz, and Walfish, 1972; Standing, 1973; Snowman, 1973). Pictures have also proved to be superior to words in free recall tasks (Dallett and Wilcox, 1968; Sampson, 1970; Snowman, 1973). Further, pictures were preferred over verbal treatments as stimulus items in paired-associate learning tasks (Kopstein and Roshal, 1954; Jenkins, 1968). Hinz (1969) stated that the visual mode had a stronger transfer effect in facilitating learning more than the verbal mode. Snowman (1973) in a review of the literature reported that due to the superiority of pictures over words for several learning tasks, there is

greater flexibility for the encoding of pictorial material than for verbal. In a review of the literature with pictorial versus verbal stimuli with young children, Hanes (1973) summarized the findings by stating that pictures significantly facilitate learning. He also said that although children are limited with respect to short term memory storage capacity and visual processing strategies, it appears that pictures are extremely useful for information communication (p. 19).

In a further review of the literature with pictorial stimuli, Levie (1973) summarized the advantages for learning in recognition memory for visuals, in free recall of pictures to words, and in paired-associate learning. The advantages of pictures as cues are limited by two conditions: when abstract rather than concrete subject matter is concerned and when the learner is lacking visual literacy as in the case of young children (pp. 38-39).

In studies dealing with visual only presentations versus verbal and visual presentations, the research favors the dual approach. In one of the first studies of this nature, Munsterberg (1894) stated that presentations which combined the sight and hearing senses improved student learning when compared to hearing only. Day and Beach (1950) in the first comprehensive review of the literature concluded that presentations which combine visual and verbal cues led to greater comprehension than either visual or verbal by itself.

Sellman (1972) found that the performance of the learners was improved when pictures were added to a verbal only text of a U.S. Air Force fire fighting training manual. In similar studies, Spangenberg (1971); Bobrow and Easton (1972); and Levie (1973) reached the same conclusion that learner performance was improved with picture and verbal presentations. Also, Peek (1974) found that pictures added to text improved reading comprehension in fourth graders. Lesgold, Levin, Shimron, & Guttman (1975) each echoed this finding with other groups

of children in prose-learning performance. Levin and Lesgold (1976) found children's verbal recall to be improved with verbal and pictorial presentations. Rasco, Tennyson, and Boutwell (1975) noticed significant results with high school students' mathematics performance when pictures were added to text. Holliday (1973) found similar results with high school biology students and science education in general.

Cropper (1966) found that learning was improved when pictorial stimuli preceded verbal or printed information. Further, less time was required for the learning tasks.

Summary

The imagery research is still controversial. Verbal, pictorial, and verbal and pictorial research has been critically investigated, and investigations continue with respect to how these stimuli are processed, stored, recalled, and used by the learner. It appears that for certain cognitive tasks (recognition memory tasks, free recall tasks, and paired-associate learning tasks) pictures are superior to words. The evidence for pictorial advantages over more traditional types of learning is stronger when pictures are added to text or verbal instruction (Fleming, 1977; Levin, Bender, and Lesgold, 1976). The evidence is beginning to emerge to form a respectable coherent pattern in media research which favors pictures and pictures and verbal instruction.

Abstract vs. Realism Theories: Visual Cue Elaboration

The amount of pictorial information in visuals has been a subject of controversy in instructional media research. This controversy stems from the amount of detail or the amount of realism in visuals (Parkhurst, 1975). During the 1940's and 1950's, it was commonly accepted that learning was enhanced when

the visualized instruction approximated reality as nearly as possible. In other words, learning was facilitated by the use of real-world photographs or models or mock-ups. The research that was conducted during this time has been collectively called the "realism theories" by Dwyer (1972). These included Dale's (1946, 1969) Cone of Experience; Morris' (1946) Iconicity theory; Carpenter's (1953) Sign Similarity theory; and Gibson's (1954) Pictorial Perception theory. Although the realism theory has been discounted in some respects, more recent research has focused on realism in visuals as a means to attract student attention and to provide motivation for learning (Yarbus, 1967; Kahneman, 1973; and Haber, 1973).

Research during the 1960's and later has largely agreed that the realism theories provide extraneous stimuli and irrelevant cues which may interfere with learning (Parkhurst, 1975). Travers (1964) supported the view that simple line drawings could provide essential visual cues in an effective and efficient manner. This view was also supported by Miller (1957); Broadbent (1958, 1965); Dwyer (1972, 1978); and Holliday (1973). This is called the relevant cue theory (Parkhurst, 1975). Broadbent (1958, 1965) and Travers (1964) considered the human memory storage capacity to be limited and of a single-channel mode. It was necessary therefore to edit reality to eliminate unnecessary stimuli.

Summary

Research in the abstract-realism continuum of visualized instruction has centered on the ability of the human memory to focus attention on incoming stimuli and to process them for later recall. Line drawings have been shown to be simple and inexpensive to produce and able to facilitate learning in an effective and efficient manner (Dwyer, 1972). For certain types of learning, either abstract or realistic visuals may be preferable. Line

drawings are appropriate for science education (Holliday, 1973) as well as for concept learning and identification (Dwyer, 1972, 1978). Real photographs and models will not be replaced in such areas as medical education and some areas of engineering since it is important for students to be able to recognize and cope with extraneous stimuli (Dwyer, 1972, 1978).

Visual Cues

Visual cues in a broad perspective include arrows, labels, italicized words, color codes, pointers, questions before or after instruction, instructions, etc. They are attention-directing techniques used to focus the learner's attention on certain stimuli (Rosonke, 1975; Dwyer, 1972, 1978).

In a review of the literature on message design in instructional visuals, Allen (1975) defined instructional media design as the manner in which the instructional message is manipulated in the design and production processes to influence the learning from that material (p. 141). He briefly summarized the literature on visual cues and stated that "relevant cues which emphasize material to be learned within an instructional communication may increase the learning of that material for all ability groups." (p. 151). Lower ability individuals may even benefit to a greater extent (Gagne and Rohwer, 1969; Rosonke, 1975; and Allen, 1975).

Allen (1975) assessed the use of arrows and other cues to be of great benefit to lower ability learners to focus attention on essential stimuli. This in effect compensates for poor attention and discrimination abilities. Higher ability learners may be handicapped by these obvious emphasizing procedures due to their ability to process information more rapidly and to focus attention selectively. (p. 153). Brown (1978) stated that arrows to focus attention may also be of

benefit when the learners have very little prior knowledge or experience with the lesson or the visual stimuli. Brown, Lewis, and Harcleroad (1973) indicated that the use of arrows as locators and clarifiers in visuals help to communicate the instructional message.

In one of the first experiments with the use of labels with visuals, Bartlett (1932) suggested that the name or title of pictorial material may play an important role in setting the background for the assimilation of information. This hypothesis was confirmed by Hall (1950).

Davies (1973) stated that using visual cues including arrows, pointers, labels, etc. contributed to learning. Research with arrows as locators and devices to focus attention in pictorial information with children emphasizes their importance as design elements (Rosonke, 1975). Arrows serve to highlight important stimuli so that children may respond in an appropriate manner. This is due to the limited capacity of children to select and process incoming information as well as limited memory storage capacities (Maccoby and Hagen, 1965; and Hanes, 1973). In assessing arrows and other visual cues as they appear in textbooks, Kennedy (1971) reported that much of the cues were overlooked by students.

When students focus attention on cue responses, researchers have found that there are several physiological reactions including pupil dilation, changes in heart rate, and changes in galvanic skin response (Meldman, 1970; Lynn, 1966; Fisher and Ong, 1972; and Hare, 1972). Eye movements from visual scanning are required for attention focusing (Kahneman, 1973). Research has shown that eye movements are a very important part of active participant-stimulus interaction (Llewellyn-Thomas, 1963; Faw and Nunnally, 1967; and Wolf and Knemeyer, 1970). Studies with television and film visuals also demonstrate the importance of arrows in the message design.

Anderson (1972) stated that arrows in television visuals can serve to minimize irrelevant and distracting stimuli. Lumsdaine, Sulzer, and Kopstein (1969) found that low ability Air Force personnel profitted from a film on learning to read a micrometer. This particular film was carefully designed with animated arrows and pop-in labels.

In conjunction with verbal and visual programs, Allen, Filep, and Cooney (1967) found that emphasis on the part of the narrator in certain points made a significant difference with low ability students. Allen, Cooney, and Weintraub (1968) in a study with film and slide/tape programs showed that emphasis by the narrator aided learning by low ability and handicapped high ability students. Dwyer (1972, 1978) found that the cueing devices may have as important a function in the transmittal of information as the information itself (1978, p. 175). Empirical data supports the use of visual cues as design elements to improve student learning (Black, 1962; Travers, 1969; Dwyer, 1972, 1978; Rosonke, 1975).

Summary

Visual cueing is an important design element in instructional visuals. Of the many types of cues used (arrows, italicized or bold-faced words, color codes, shading, etc.) arrows are an important device to focus the attention of the viewer on particular stimuli. Arrows may show direction, location, position, as well as motion, flow and movement. The research indicates that for children and handicapped learners, arrows are very important. With children, arrows help to single out stimuli for encoding. With handicapped learners, arrows may in essence provide added ability to process information. With more advanced groups, arrows may prove to be a hindrance. It is evident that arrows serve an important function with all learners.

Mode of Presentation

The two basic strategies for conveying information to the learners are the externally-paced mode of presentation and the internally-paced mode of presentation. External pacing means that the visual material is linearly programmed and presented sequentially so that a) all students receive the visuals at the same level of sophistication and b) all students view the material for the same length of time. Internal pacing means that the material is presented to the student so that a) the individual may interact with it for any length of time and b) he or she may refer back to any previous visual for review or clarification (Dwyer, 1978, p. 64).

Time is an important element here. Information inputs require a certain amount of processing time (Feigenbaum and Simon, 1963; Broadbent, 1965). Carrol (1963) stated that learning is dependent on the amount of time an individual spends actively engaged in that learning. Harless, Parker, Lucas, and Nunnery (1969) and Mackworth (1962) assessed the effects which time has on learning, and the conclusion was that learning is a function of the rate at which the information was presented to the learners. Rudnick, Porter, and Snydam (1973) professed that "when the learner has the time and the visual literacy necessary to obtain additional information provided by realism cues, additional, often incidental learning may occur." (p. 28). Time on task is an important instructional variable which affects the types of visuals which should be selected in accordance with the learning objectives (Dwyer, 1978, p. 75).

Dwyer (1972, 1978) in numerous studies with high school and college age pupils with the same types of instructional visuals has found that the mode of presentation combined with the type of visual have certain implications for learning. Dwyer (1972) concluded that simple line drawings are best suited

for externally-paced presentation and more complex visuals are best suited for internally-paced presentation. This is a function of time with which the student may interact with the visuals and the complexity of them. This finding has also been put forth by Fleming and Sheikhian (1972) and by Joseph (1979).

In a study of paired-associate learning, Wicker (1970) found that there was no difference with line drawings or with detailed pictures with externally-paced presentations. Holliday (1973) stated that further research needed to be undertaken with types of visuals and modes of presentation in science education.

Summary

It is evident that time on task is a critical variable in instructional design when considered with simple and complex visuals (Bloom, 1974). In numerous studies with visually equivalent instructional units, Dwyer (1972) reported that learning was optimized for certain learning objectives when externally-paced presentation accompanied more complex visuals.

Verbal and Visual Memory Processes

There are conflicting theories regarding the mechanisms by which the human memory processes, stores, and recalls verbal and visual information. The first theory is the single system hypothesis which processes verbal information. The second theory, the dual coding system hypothesis states that there are indeed separate memory mechanisms which process verbal and pictorial stimuli for later recall.

The verbal-loop hypothesis (Glanzer and Clark, 1963) proposed that pictorial stimuli were processed in memory by first translating the information into a series of words. This is

a covert verbalization and verbal storage of pictorial information. The assumption underlying this process is the length of verbalization required by the task (Glanzer and Clark, 1963). Other researchers support this view (Lantz and Stefflre, 1964; Travers, 1964; and Ghatala, Levin, and Wilder, 1973).

The dual system hypothesis is postulated by Paivio (1971). In this dual coding theory there are two memory systems. One system processes verbal information, and the other system processes pictorial information. These two systems operate independently, but are richly interconnected and may also operate in conjunction with each other (Levie and Levie, 1975, p. 83). Either system may also arouse the other and process information accordingly. This additive effect is important since information may now be stored dually, in both systems, or one system may be more developed in an individual (Fleming and Sheikhian, 1972, p. 425). Other researchers in agreement with this model are Davies (1969); Kaplan, Kaplan, and Sampson (1968); and Bower (1972).

The evidence fron neurophysiological research seems to favor the dual coding philosophy. Physiological and psychological research has demonstrated that the right and left hemispheric laterality of the human brain represents different functions. The left hemisphere dominates for tasks involving abstract reasoning and verbal or linguistic functions. The right hemisphere dominates for tasks involving perceptual and nonverbal functions (Sperry, 1961; Milner, 1970; and Geffen, Bradshaw, and Wallace, 1971). Electroencephalograph (EEG) patterns tend to indicate this relationship (Galin and Ornstein, 1972; and Wheatley, 1979). Studies with patients with surgically separated hemispheres by Gazzaniga (1970) and Sperry (1973) support the differential functions of the brain hemispheres.

Separate information processing mechanisms are further suggested by Milner and Teuber (1968) who reported that persons with damaged right hemispheres affected nonverbal memory without affecting verbal memory. Kimura (1973) reported similar results through an experiment with normal persons who received differential verbal and visual treatments.

Behavioral evidence also seems to support the dual coding hypothesis. Bahrick and Boucher (1968) reported that verbal recall of labels in simple visuals was not related to correct visual recognition of the drawing. This was further evidenced in free recall studies (Bahrick and Bahrick, 1971); in verbal discrimination learning (Rowe, 1972); in paired-associate learning (Nelson and Brooks, 1973); and in pictorial recognition studies (Snodgrass, Wasser, Finkelstein, and Goldberg, 1974).

In other types of studies, testing for an interaction between the visual and the verbal modes, den Heyer and Barrett (1971); Neudell (1972); and Murray and Newman (1973) all reported an interaction. Similar results were found by Atwood (1971); and Kernes and Yuille (1972).

In recognition tasks, the research supports the notion that human memory has a greater capacity for pictorial information processing then for verbal (Shepard, 1967; Hinz, 1969; and Standing, Conezio, and Haber, 1970). For some recall tasks, pictorial is again stronger than verbal (Paivio and Csapo, 1973). The research seems to strongly favor the dual processing theory.

Summary

The mechanisms by which human beings process, store, and recall pictorial and verbal stimuli are not completely understood. To explain the mechanisms, two major

theories have evolved. Glanzer and Clark (1963) proposed the single mode process, and Paivio (1971) proposed the dual coding hypothesis. Neurophysiological, psychological, and educational research seems to favor the dual processing theory, although much more research is required in these areas.

Conclusion

This review of the literature was intended to lend some organization to media research with line drawings and visual cues. It is comprehensive within certain constraints of time and practicality. It is evident that the research is often equivocal in its findings and many conflicting theories have evolved. It is the impression of this writer that some areas of high technology (particularly laser scanning and bio-medical technology) may lead the way to developing new techniques that can be applied to media research to further identify and track the educational and psychological processes that affect learning and memory.

BIBLIOGRAPHY

Allen, W.H. Intellectual abilities and instructional media design. AV Communication Review, 1975, 23, 139-170.

Allen, W.H., Cooney, S.M., & Weintraub, R. Audio implementation of still and motion pictures. USOE Final Report, Project No. 5-0741. Los Angeles, CA: University of Southern California, Research Division, 1968.

Allen, W.H., Filep, R.F., & Cooney, S.M. Visual and audio presentation of machine-programmed instruction. USOE Final Report, Project No. 5-0724-2-12-1. Los Angeles, CA: University of Southern California, Research Division, 1967.

Anderson, C.M. In search of a visual rhetoric for instructional television. AV Communication Review, 1972, 20, 43-63.

Bahrick, H.P. & Bahrick, P. Independence of verbal and visual codes of the same stimuli. Journal of Experimental Psychology, 1971, 91, 344-346.

Bahrick, H.P. & Boucher, B. Retention of visual and verbal codes of the same stimuli. Journal of Experimental Psychology, 1968, 78, 417-422.

Bartlett, F.C. Remembering. Cambridge, 1932.

Black, H.B. Improving the programming of complex pictorial materials. NDEA Title VII Report, Project No. 688, U.S. Office of Education, 1962.

Bloom, B.S. Time and learning. American Psychologist, Sept., 1974, 682-688.

Bobrow, S.A. & Easton, R.D. A confirmation that relational organization facilitates memory. Psychonomic Science, 1972, 29, 256-257.

Bower, G.H. Perceptual groups as coding units in immediate memory. Psychonomic Science, 1972, 27, 217-219.

Broadbent, D.E. Perception and communication. New York: Pergamon, 1958.

Broadbent, D.E. Information processing in the nervous system. Science, 1965, 3695, 457-462.

Brown, J.W. Educational Media Yearbook 1978. New York: R.R. Bowker, 1978.

Brown, J.W., Lewis, R.B., & Harcleroad, F.F. AV Instruction: Technology, Media, and Methods. New York: McGraw-Hill, 1973.

Carpenter, C.R. A theoretical orientation for instructional film research. AV Communication Review, 1953, 1, 38-52.

Carrol, J.B. A model of school learning. Teachers College Rec., 1963, 64, 723-733.

Chu, G.C. & Schramm, W. Learning from Television: What the Research Says. Washington, D.C.: National Association of Educational Broadcasters, 1979.

Dale, E. Audio-visual Methods in Teaching. New York: Dryden, 1946.

Dallet, K., Wilcox, S.G., & D'Andrea, L. Picture memory experiments. Journal of Experimental Psychology, 1968, 76, 312-320.

Day, W.F., & Beach, B.R. A Survey of the Research Literature Comparing Visual and Auditory Presentation of Information. Wright Patterson Air Force Base. Air National Command: USAF Technical Report. No. 5921.

den Heyer, K., & Barrett, B. Selective loss of visual and verbal information in STM by means of visual and verbal interpolated tasks. Psychonomic Science, 1971, 25, 100-102.

Dwyer, F.M., Jr. A Guide for Improving Visualized Instruction. State College, PA: Learning Services, 1972.

Dwyer, F.M., Jr. Strategies for Improving Visual Learning. State College, PA: Learning Services, 1978.

Faw, T.T., & Nunnally, J.C. The effects of eye movement of complexity, novelty, and affective tone. Perception and Psychophysics, 1967, 2, 363-367.

Feigenbaum, E.A., & Simon, H.A. Brief notes on the theory of verbal learning. In Confer, C.N., Musgrave, B.S. (Eds.), Verbal Behavior and Learning. New York: McGraw-Hill, 1963.

Fleming, M.L. The picture in your mind. AV Communication Review, 1977, 25, 43-62.

Fleming, M.L., & Sheikhian, M. Influence of pictorial attributes on recognition memory. AV Communication Review, 1972, 20, 423-441.

Gagne, R.M., & Rohwer, W.D., Jr. Instructional psychology. Annual Review of Psychology, 1969, 20, 381-418.

Galin, D., & Ornstein, R. Lateral specialization of cognitive mode: An EEG study. Psychophysiology, 1972, 9, 412-418.

Gazzaniga, M.S. The Bisected Brain. New York: Appleton, 1970.

Geffen, B., Bradshaw, J.L., & Wallace, R. Interhemispheric effects on reaction time to verbal and nonverbal stimuli. Journal of Experimental Psychology, 1971, 87, 415-422.

Ghatala, E.S., Levin, J.R., & Wilder, L. Apparent frequency of words and pictures as a function of pronunciation and imagery. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 85-90.

Gibson, J.J. A theory of pictorial perception. AV Communication Review, 1954, 2, 2-23.

Glanzer, M., & Clark, W.H. The verbal loop hypothesis: binary numbers. Journal of Verbal Learning and Behavior, 1963, 2, 301-309.

Gropper, G.L. A Technology for Developing Instructional Materials. Pittsburgh, PA: American Institutes for Research, 1973.

Gropper, G.L. Learning from Visuals: some behavioral considerations. AV Communication Review, 1966, 14, 37-69.

Haber, R.N., & Herschenson, M. The Psychology of Visual Perception. New York: Holt, Rinehart and Winston, 1973.

Hall, K.R. The effect of names and titles upon the serial reproduction of pictorial and verbal material. The British Journal of Psychology, General Section, 1950, XLI, 109-121.

Hanes, M.I. Research on how children learn from pictures. Viewpoints. 1973, 49, 11-20.

Hare, R.D. Response requirements and directional fractionation of autonomic responses. Psychophysiology, 1972, 9, 427-429.

Harless, W.G., Parker, H.J., Lucas, N.C., & Nunnery, A.W. The total time hypothesis and computer assisted instruction. Educational Technology, 1969, 9, 86-90.

Hinz, M. Effect of response mode on learning efficiency. AV Communication Review, 1969, 17, 77-83.

Holliday, W.G. Critical analysis of pictorial research related to science education. Science Education, 1973, 57, 201-214.

Hunt, E.B. Concept Learning. New York: Wiley, 1962.

Jenkins, J.R. Strategies on paired-associate learning. Journal of Educational Psychology, 1968, 59, 410-413.

Joseph, J.H. The Instructional Effectiveness of Integrating Abstract and Realistic Visualization. Paper presented at AECT National Convention, New Orleans, LA, 1979, ERIC DOC. ED172799.

Kahneman, D. Attention and Effort. Englewood Cliffs, N.J.: Prentice-Hall, 1973.

Kaplan, W., Kaplan, R., & Sampson, J.R. Encoding and arousal factors in free recall of verbal and visual material. Psychonomic Science, 1968, 12, 73-74.

Kennedy, L.D. Textbook usage in the intermediate-upper grades. The Reading Teacher, 1971, 24, 723-729.

Kimura, D. The asymmetry of the human brain. Scientific American, 1973, 228, 70-78.

Kopstein, F.F., & Roschal, S.M. Learning foreign vocabulary from pictures versus words. American Psychologist, 1954, 9, 407-408.

Lantz, D., & Stefflre, V. Language and cognition revisited. Journal of Abnormal and Social Psychology, 1964, 69, 472-481.

Levie, W.H. Pictorial research: an overview. Viewpoints, 1973, 49, 37-46.

Levie, W.H., & Levie, D. Pictorial memory processes. AV Communication Review, 1975, 23, 81-97.

Levin, J.R. On Functions of Pictures in Prose. Washington, D.C.: DHEW, 1979, ERIC DOC. ED 186847.

Levin, J.R., Bender, B.G., & Lesgold, A.M. Pictures, repetition, and young children's oral prose learning. AV Communication Review, 1976, 24, 367-380.

Levin, J.R., & Lesgold, A.M. On pictures in prose. ECTJ, 1978, 26, 233-244.

Llewellyn-Thomas, E. Eye movement of a pilot during aircraft landings. Journal of Aerospace Medicine, 1963, 34, 424-426.

Lordahl, D.S. Concept identification using simultaneous auditory and visual signals. Journal of Experimental Psychology, 1961, 62, 283-290.

Lumsdaine, A.A., Sulzer, R.L., & Kopstein, F.F. The effect of animation cues and repetition of examples on learning from an instructional film. In Lumsdaine, A.A. (Ed.), Student Response in Programmed Instruction. Washington, D.C.: National Academy of Science and National Research Council, 1961.

Lynn, R. Attention, Arrousal and the Orientation Reaction. New York: Pergamon, 1966.

Maccoby, E.E., & Hagen, J.W. Effects of distraction upon central versus incidental recall: development trends. Journal of Experimental Child Psychology, 1965, 2, 280-289.

Mackworth, J.F. Presentation rate and immediate memory. Canadian Journal of Psychology, 1962, 16, 43-47.

MacLennan, D.W., & Reid, J.C. Research in Instructional Television and Film, Washington, D.C.: U.S. Office of Education, 1967.

Meldman, M. Diseases of Attention and Perception. New York: Pergamon, 1970.

Meudel, P.R. Short-term visual memory: comparative effects of two types of distraction on the recall of visually presented verbal and nonverbal material. Journal of Experimental Psychology, 1972, 94, 244-247.

Miller, N.E. Graphic communication and the crisis in education. AV Communication Review, 1957, 5, 11-20.

Milner, B., & Teuber, H.L. Alteration of perception and memory in man: reflections on methods. In Weiskrantz, L. (Ed.), Analysis of Behavioral Changes. New York: Harper & Row, 1968.

Morris, C.W. Signs, Languages, and Behavior. New York: Prentice-Hall, 1946.

Moses, B.E. The Relationship between Visual Thinking Tasks and Problem-solving Performance. Paper presented at the Annual Meeting of the American Educational Research Association, Boston, 1980, ERIC DOC. ED 187734.

Munsterberg, H., & Bigham, J. Studies from the Harvard Psychology Laboratory. Psychological Review, 1894, 1, 34-38.

Murray, D.J., & Newman, F.M. Visual and verbal coding in short-term memory. Journal of Experimental Psychology, 1973, 100, 58-62.

Nelson, D.L., & Brooks, D.H. Functional independence of pictures and their verbal memory codes. Journal of Experimental Psychology, 1973, 98, 44-48.

Paivio, A. Imagery and Verbal Processes. New York: Holt, Rinehart and Winston, 1971.

Paivio, A., & Csapo, K. Concrete-image verbal memory codes. Journal of Experimental Psychology, 1969, 80, 279-285.

Paivio, A., & Csapo, K. Short-term sequential memory for pictures and words. Psychonomic Science, 1971, 24, 50-51.

Parkhurst, P.E. Generating meaningful hypothesis with aptitude-treatment interactions. AV Communication Review, 1975, 23, 171-183.

Peek, J. Retention of pictorial and verbal content of text with illustrations. Journal of Educational Psychology, 1974, 66, 880-888.

Rasco, R.W., Tennyson, R.D., & Boutwell, R.C. Imagery instructions and drawings in learning prose. Journal of Educational Psychology, 1975, 67, 188-192.

Rosonke, R.J. A Study of the Effectiveness of Three Visual Attention-Directing Devices on the Recall of the Relevant Information from Line Drawings. Unpublished doctoral dissertation, University of Iowa, 1974.

Rowe, E.J. Imagery and frequency processes in verbal discrimination learning. Journal of Experimental Psychology, 1972, 95, 140-146.

Rudnick, M.F., Porter, M.C., & Suydam, E.L. Pictorial stimulus variables. Viewpoints, 1973, 49, 21-28.

Sampson, J.R. Free recall of verbal and non-verbal stimuli. Quarterly Journal of Experimental Psychology, 1970, 22, 215-221.

Sellman, W.S. Reducing the literacy of training materials as one means of increasing learning in low-ability personnel. Journal of Experimental Education, 1972, 41, 54-59.

Shepard, R.N. Recognition memory for words, sentences, and pictures. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 156-163.

Snodgrass, J.G., Volvovitz, R., & Walfish, E.R. Recognition memory for words, pictures, and words and pictures. Psychonomic Science, 1972, 27, 345-347.

Snodgrass, J.G., Wasser, B., Finkelstein, M., & Golberg, L.B. On the fate of visual and verbal memory codes for pictures and words. Evidence of a dual coding mechanism in recognition memory. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 27-37.

Snowman, J. The research on how adults learn from pictures. Viewpoints, 1973, 49, 1-10.

Spangenberg, R.W. Structural coherence in pictorial and verbal displays. Journal of Educational Psychology, 1971, 62, 514-520.

Sperry, R.W. Cerebral organization and behavior. Science, 1961, 133, 1749-1756.

Sperry, R.W. Lateralization of function in the surgically separated hemispheres. In McGuigan, F.J., & Schoonover, R. (Eds.), The Psychophysiology of Thinking. New York: Academic, 1973.

Standing, L. Learning 10,000 pictures. Quarterly Journal of Experimental Psychology, 1963, 25, 207-222.

Standing, L., Conezio, J., & Haber, R.N. Perception and memory for pictures: single-trial learning of 2500 visual stimuli. Psychonomic Science, 1970, 19, 73-74.

Stewig, J.W. From Visuals to Words. Paper presented at the Annual Conference of the Midwest Association for the Education of Young Children, Milwaukee, 1980, ERIC DOC. ED 186111.

Swamson, R.A., Lumsdaine, A.A., & Aukes, L.E. In Finch, G., Cameron, F. (Eds.), Symposium on Air Force Human Engineering: Personnel and Training Research. Washington, D.C.: National Academy of Sciences - National Research Council Pub. No. 455, 1956.

Ternes, W., & Yuille, J.C. Words and pictures in STM memory task. Journal of Experimental Psychology, 1972, 96, 78-86.

Travers, R.M.W. Transmission of information to human receivers. Educational Psychologist, 1964, 2, 1-5.

Travers, R.M.W. A Study of the Advantages and Disadvantages of Using Simplified Visual Presentations in Instructional Materials. Final Report, U.S.D.H.E.W., Office of Education, 1969.

Walker, C.M., & Bourne, L.E. The identification of concepts as a function of amount of relevant and irrelevant information. American Journal of Psychology, 1961, 74, 410-417.

Wheatley, G.H. Right hemisphere's role in problem solving. Arithmetic Teacher, 1977, 25, 36-39.

Wicker, F.W. On the locus of picture-word difference in paired-associate learning. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 52057.

Wolf, W., Knemeyer, M. A Study of Eye Movement in Television Viewing. U.S.O.E. Final Report, Project No. 5-0427, Ohio State Univ., 1970.

Yarbus, A.L. Eye Movements and Vision. New York: Plenum, 1967.